Column Retrofitting By Using Hybrid Fibre Reinforced Epoxy Composite Laminates (HFRECL)

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Abstract - **Significant amount of research work has been carried out in recent years to develop various strengthening and rehabilitation techniques to improve the seismic performance of structures. HFRECL has started to be used to increase the flexural potency of members. To increase flexural power, the HFRECL should be glued to the member in the way that fibres are parallel to the direction of the principal stress. Basically the technique involves gluing steel plates or fiber reinforced polymer (HFRECL) plates to the surface of the concrete. The plates then act compositely with the concrete and help to bear the loads. Each material has its specific advantages and disadvantages. Steel plates have been used for many years and are very successful to use as bonding reinforcement. However, they are heavy to transport and install, prone to corrosion and delivery length of plates are limited. The aim of the present work is to study the behaviour of reinforced concrete columns strengthened using Glass Fibre Reinforced Polymer (GFRP) and Carbon Fibre Reinforced Polymer (CFRP) subjected to axial loading. The basic conceptual idea is to use HFRECL only in those zones of the structure where the outstanding HFRECL properties in terms of durability and strength are fully exploited; i.e. HFRECL is used to "harden" the zones where the structure is exposed to severe environmental conditions (ex., deicing salts, marine environment) and high mechanical loading (ex. impact, concentrated loads, fatigue). The energy absorbed by the column wrapped with both GFRP and CFRP was much superior than the column without FRP wrapping.**

keywords - **Reinforce, Composites, Laminates, Polymer, concrete.**

I INTRODUCTION

Reinforced concrete structures show excellent performance in terms of structural behaviour and durability except for those zones that are exposed to severe environmental influences and high mechanical loading. Rehabilitation of deteriorated concrete structures is a heavy burden from the socio-economic viewpoint since it leads to significant user costs. As a consequence, novel concepts for the rehabilitation of concrete structures must be developed. Sustainable concrete structures of the future will be those requiring just minimum interventions of only preventive maintenance with no or only little service disruptions.

In recent times, there has been a worldwide increase in the use of composite materials for the rehabilitation of deficient reinforced concrete (RC) structures. One important application of this composite retrofitting technology is the use of fiber reinforced polymer (HFRECL) jackets or sheets to provide external confinement to RC columns when the capacity of existing structure is inadequate. HFRECL can therefore be convenient compared to steel. These materials have higher ultimate strength and lower density than steel. The installation is easier and temporary support until the adhesive gains its strength is not required due to the low weight. They can be formed on site into complicated shapes and can also be easily cut to length on site.

Debonding is a major problem in structures retrofitted with HFRECL. Debonding implies complete loss of composite acti1on between concrete and HFRECL. This prevents full utilization of the HFRECL - concrete system and may lead to failure before the design load is reached. Debonding due to a stress concentration may initiate either at the plate end or around cracks. This work is a study of the behaviour of concrete beams retrofitted with HFRECL, using experiments and finite element modelling. One main focus is the debonding issues that limit the composite system from achieving the desired load capacity.

II OBJECTIVE AND LITERATURE

A. Objective

The aim of the present work is to study the behavior of hybrid fibre reinforced composite laminate (HFRECL) retrofitted to reinforced concrete columns and compare the results to the unretrofitted reinforced concrete columns under axial loads.

B. Review of literacture:

Alessandra Aprile et al (2001), found that RCC beams strengthened by steel plates showed a malleable response, mainly due to compliant of the strengthening plate. The RCC beams strengthened by CFRP plates showed a fragile response, as the response was subjugated by the elastic behaviour of the plate.

Omar Ahmed et al (2001), has proposed design formulae to expect the strength of Carbon-Fibre-Reinforced Plastic (CFRP) strengthened beams, particularly when untimely failure through laminates-end trim or concrete cover delamination occurs. The predictions using the planned formulae were compared with the experimental results, as well as with the calculated design bound states.

Francesco Bencardino et al (2002), conducted an experimental investigation of resistant concrete beams strengthened in flexure and clip using externally epoxy bonded bidirectional carbon fibre fabric to conquer the bond trip and plate separation at the ends. In conclusion that the results reported herein show that CF fabrics can provide an successful and competent alternative to laminates strengthening obtainable concrete structures.

Rania AI-Ham et al (2006) investigated on flexural behaviour of decomposed steel reinforced concrete beams under frequent loading. This investigation was approved out on thirty beams of sizes 152x254x2000mm repaired with carbon fibre toughened polymer (CFRP) sheets. The authors reported that repairing with CFRP sheets increased the weariness capacity of the beams with putrefied steel reinforcement beyond that of the manage unrepaired beams with un-corroded steel corroboration. Beams repaired with 10 CFRP at a medium corrosion level and then further putrefied to a high corrosion level before testing had a equivalent fatigue performance to those that were repaired and tested after corroding straight to a high corrosion intensity.

Abdelhak Bousselham and Omar Chaallal (2006), made an experimental examination on the behaviour of reinforced tangible T-beams retrofitted in shear with outwardly bonded CFRP composite. The authors accomplished that the shear competence gain due to the CFRP was superior for profound specimens than for slender specimens.

Carlos and Maria (2006), conducted an experiment and found numerical results validated in opposition to experimental data obtained from 19 beams strengthened with different types of FRP. They derived the arithmetic simulations and which indicates that the concrete tensile potency does not represent the unique collapse criterion for predicting plate debonding breakdown of strengthened RC beams.

Murat Tanarslan et al (2010) concluded that the CFRP composites have no ductility as a substance and this could lead to adverse brittle failure in the strengthened essentials. Specimens were also greatly damaged. Conversely, ductility of 1.04 to 1.99 was obtained from the repaired and strengthened specimens. It was not feasible to state that the CFRP strengthened RC beams behaved in a flexible way, but the result achieved were still striking.

Jadhav and Shiyekar (2011) carried out experimental study, to examine the consequence of length, width and number of layers of glass fibre reinforced polymer (GFRP) strips applied to the pressure side of the RC Beam. The authors concluded that, the beam strengthened with different breadth and number of layers of glass fibre reinforced polymer (GFRP) strips exhibited relatively superior ductile behaviour. However, it showed identical weight at yielding of steel. This was because the glass fibre reinforced polymer had superior primary stiffness. Therefore, it contributed to strengthening more efficiently. The load carrying of the strengthened beams increased by 7% to 35% when compared to the manage beam.

III. MATERIALS USED AND METHODOLOGY

The materials used in this study included ordinary Portland cement, fine collection (manufactured sand), coarse aggregate, combination of water, CFRP sheets, GFRP sheets and epoxy resin. The cement used in all mixtures of the study was 53 grade Ordinary Portland cement, which conforming to IS 12269:2013. The fine aggregate style used in the study was manufactured sand. The coarse aggregate of size 20mm was used in the study. Potable water was used for mixing and therapeutic of specimens all through the experimentation. Unidirectional CFRP and GFRP sheets of thickness 0.3mm were used for the study shown in fig 1. Araldite AW106 with Hardener HV 953 IN was used as epoxy resin in order to bind FRP sheets to concrete and also to tie layers of FRP sheets jointly. Equal quantity of Araldite and Hardener are mixed thoroughly inorder get sufficient binding assets.

Axial Testing Of Concrete Columns Confined With HFRECL:

Effect of Fibre Orientation

Reinforced concrete columns need to be laterally confined in order to ensure large deformation under load and provide adequate resistance capacity. In the case of a seismic event, energy dissipation allowed by a well- confined concrete core can often save human lives. On the contrary, a poorly confined concrete column behaves in a brittle manner leading to sudden and catastrophic failures Steel jacketing provided by hoops or ties exerts a constant confining pressure as soon as the steel has yielded. When a perfectly elastic material such as HFRECL is used, the confining pressure on concrete keeps increasing as the load and volumetric expansion increases. This new behavior has to be understood and a different approach to the theory has to be taken Piers and columns upgraded by using externally bonded HFRECL laminates has been proven to be a reliable technique to enhance flexural and shear capacity, and improve ductility as well as increase ultimate load carrying capacity. Theoretical models taking into account confining pressure due to either steel or HFRECL are available. However, in this paper, findings and equations developed by ACI Committee 440 will be used as the analytical framework for both rectangular and circular columns.

EXPERIMENTAL INVESTIGATION

Test Specimen Details

Experiments were conducted on six, one-third scaled columns. The height of the column is 1000mm and of 200 mm x320 mm size. Reinforcement details for the column are shown in Figure below . Column is made with M20 grade concrete and Fe-415 grade steel is used for longitudinal reinforcements and Fe-250 grade steel is used for stirrups and lateral ties. The columns are longitudinally reinforced with 4 Nos. of 13mm diameter bars and laterally tied with 6mm diameter bars placed at 100 mm c/c. The same reinforcement was provided for beams also.Three specimens were jacketed externally by 2, 4 and 6 layers of GFRP sheets. Before jacketing the specimens with GFRP sheets, a surface preparation was carried out, which included cleaning, forming one layer of epoxy-polyamine primer and one layer of epoxy putty, then epoxy adhesive was used for bonding GFRP sheets on the specimens. Additional layers of epoxy adhesive were applied between GFRP sheets. Two specimens were jacketed externally by single layer of CFRP sheet. Before jacketing the specimens with CFRP sheets, a surface preparation was carried out, which included cleaning, forming one layer of epoxy-polyamine primer and one layer of epoxy putty, then epoxy adhesive was used for bonding CFRP sheet on the specimens. One specimen was tested without any wrapping.

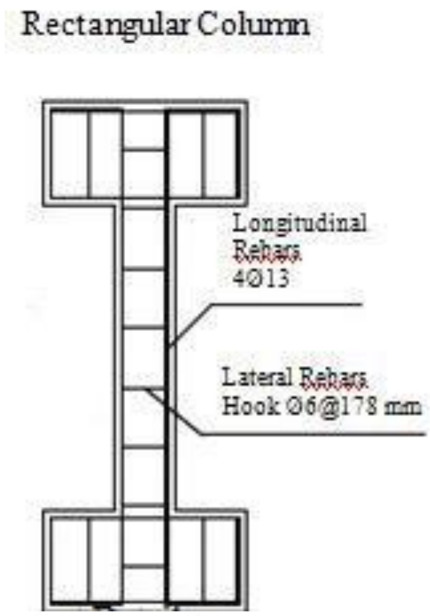


Fig 1

Test Set-Up –The test set up consist of a reaction frame, a hydraulic actuator of capacity 200 kN with a stroke length of ± 100mm and a loading frame with hydraulic jack of 50 kN to apply loads to the test specimens. 50 kN reversed cyclic load on the specimens. A steel reaction frame was used to support the 200 kN actuator providing lateral load to the specimen. Instrumentation included Linear Voltage Differential Transducers (LVDT) for lateral displacement measurement at the top of the column and one load cell attached to the actuator was used for the measurement of cyclic lateral loads. A loading frame was used to apply a vertical constant axial load through steel rollers placed with the support of steel plates in between the jack and column head. The vertical load was chosen to a design compression rate of 0.45 RC axial resistance found in the analysis. The experimental set-up for both GFRP and CFRP specimens were shown in Figure 2.

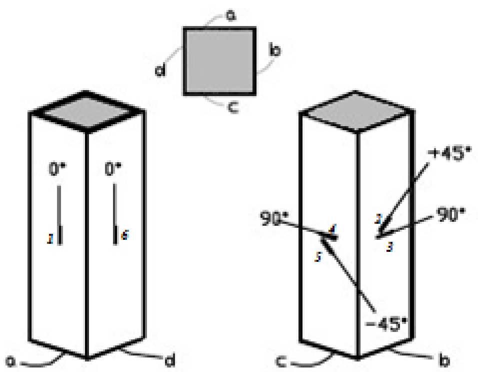
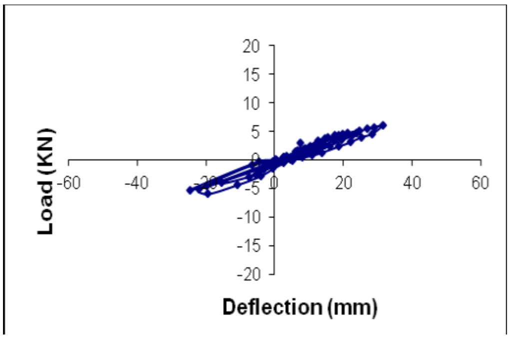


Fig 2: LVDT position

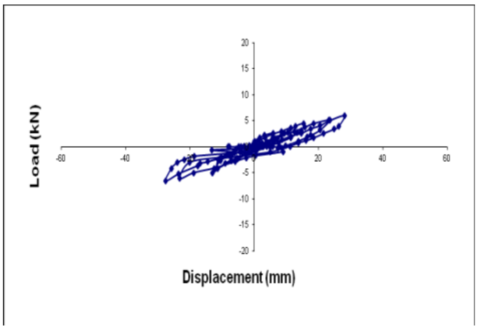
IV. TEST RESULTS AND DISCUSSION

Observed Failure modes—Figure 3 shows the failure pattern of the test specimens. In the specimen without FRP wrapping (GFC 0), failure was due to concrete crushing at the beam-column junction and minor cracks were noticed along the height of the column as shown in Fig.3(a). For the other Glass fibre wrapped and Carbon fibre wrapped specimens, failure occurred due to the fracture of GFRP and CFRP composite at the beam-column junction due to the stress concentration in those regions. In all the cases, the columns failure was the result of the rupture of the FRP jacket, associated with concrete crushing at the beam-column junction and marked by wraps rupturing in the circumferential direction. Approaching failure load, the appearance of white patches was found, which indicated the yielding of fibre glass and resin.

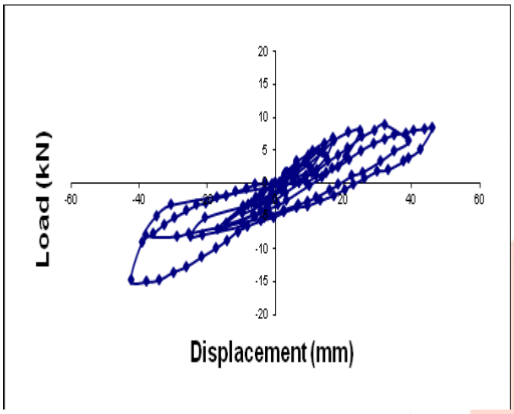
Lateral Load versus Lateral Displacement Curve—The variation of lateral displacement with that of the lateral load was plotted for all the specimens as shown in Figure 4. From the load-displacement curves it is observed that the unwrapped specimen GFC 0 failed at a load of 6.1kN with a lateral displacement of 31.5 mm. The GFRP wrapped specimens GFC 1, GFC 2 and GFC 3 failed at loads of 6.6 kN, 7.8 kN and 8.4 kN with the corresponding displacements of 33 mm, 38.5 mm and 46.12 mm. The CFRP wrapped specimens CFC 1 and CFC 2 failed at loads of 12.05 kN and 12.15 kN with the corresponding displacements of 51.08 mm and 51.67 mm.



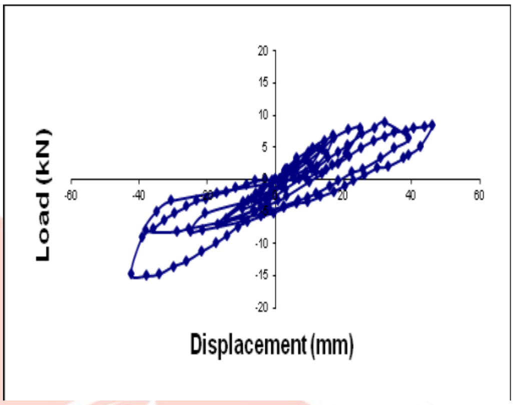
(a) Specimen GFC 0 (Unwrapped)



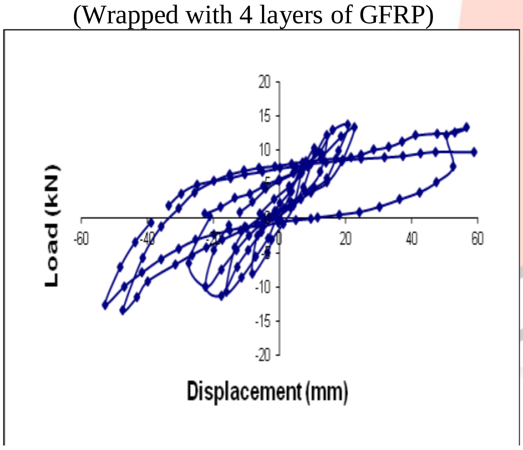
(b-i) Specimen GFC 1
(Wrapped with 2 layers of GFRP)



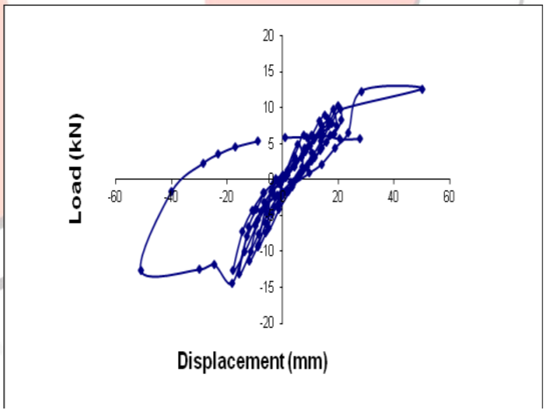
(b - ii) Specimen GFC 2
(Wrapped with 4 layers of GFRP)



(b-iii) Specimen GFC 3
(Wrapped with 6 layers of GFRP)



(c-i) Specimen CFC 1
(Wrapped with 1 layer CFRP)



(c-ii) Specimen CFC 2
(Wrapped with 1 layer CFRP)

Figure 3. Load-displacement curves for the 6 specimens

V . CONCLUSIONS

This paper presents an experimental and analytical investigation conducted to assess the behaviour of column wrapped with GFRP and CFRP. One specimen without FRP wrapping, three specimens with 2, 4 and 6 layers of GFRP and two specimens with one layer of CFRP were tested. The following conclusions were drawn based on the results of cyclic tests.

The column specimens wrapped with two layers, four layers and six layers of GFRP shows 8%, 28% and 32% increase in the load carrying capacity respectively compared to the specimen without wrapping.

The specimen jacketed with 6 layers of GFRP has the highest load carrying capacity and there is 32% increase in the strength compared with the specimen without GFRP wrapping.

The column specimens wrapped with two layers, four layers and six layers of GFRP shows 25%, 54% and 70% increase in ductility respectively compared to the specimen without wrapping. The specimen jacketed with 6 layers of GFRP has the highest ductility and there is 70 % increase in the ductility compared with the specimen without GFRP wrapping.

The specimens jacketed with CFRP have an average of 98.3% increase in the strength capacity compared to the specimen without CFRP wrapping.

There is an average 2.7% increase in ductility for the specimens wrapped with CFRP when compared to the specimen without CFRP wrapping.
It is observed that at low displacement levels, the energy absorbed by both GFRP and CFRP wrapped specimens were less than that by the specimen without FRP wrapping.
At higher levels of lateral displacement, the energy absorbed by thecolumn wrapped with both GFRP and CFRP was much higher than the column without FRP wrapping. 71.
The analytical results are in good agreement with the experimental findings and the percentage variation is within 10%
Even though, the load carrying capacity of CFRP wrapped specimen with one layer of jacketing is 98.3% and 70% for GFRP with 6 layers of wrapping, the ductility of CFRP wrapped specimen is increased only 2.7% compared to the increase in ductility of 70% for GFRP with 6 layers of wrapping. All these comparisons are made with respect to unwrapped control specimen.
The increase in cost of construction for CFRP wrapping is 43% compared to specimen with 6 layers of GFRP wrapping.

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